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The general goals of this project included the development of new, high-order, adaptive methods for the computer simulation of stress-wave propagation phenomena in solid mechanics, particularly elastodynamics.

The motivation for using adaptive methodologies is to control and optimize the computational process, to use a posteriori error estimates to optimize meshes and spectral orders of approximation. Such orchestrated meshing can produce exponential rates of convergence, thereby allowing complex simulations to be done using orders-of-magnitude fewer unknowns than standard methods.

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Hp-ADAPTIVE FINITE ELEMENT METHODS FOR TIME DEPENDENT PROBLEMS WITH APPLICATIONS TO STRESS WAVES IN SOLIDS

FINAL PROGRESS REPORT

Professor J. Tinsley Oden
The University of Texas at Austin

August, 1996

U.S. ARMY RESEARCH OFFICE

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THE UNIVERSITY OF TEXAS AT AUSTIN

FINAL PROGRESS REPORT
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Statement of Problem Studied

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Summary of Results

This project has led to a number of completely new and powerful methods for the computer simulation of complex problems, including, in particular, problems of wave propagation. These include the following:

- High-Order Multistage-Taylor Galerkin Methods. These represent one of the only new unconditionally stable high-order time integration schemes developed in decades. They are designed to overcome a well-documented deficiency of splitting methods: the loss of time accuracy due to splitting of boundary conditions.
- A Posteriori Error Estimation Methods. New techniques for the estimation of error in numerical approximations of wave problems in two space dimensions have been developed; theorems have been established to guarantee that rigorous error bounds are possible.
- Adaptive methods. Local error estimates provide data for adaptively changing mesh sizes and spectral orders to optimize hp meshes and accelerate convergence.
- Parallel Discontinuous Methods. A surprisingly parallelizable scheme based on Discontinuous Galerkin methods has been developed and tested on model problems.
- Clouds: A New family of Meshless Methods. Error estimates and preliminary results on the mathematical foundations of a new type of meshless technique for solving partial differential equations have been established.

List of Publications

Safjan, A. and Oden, J.T., "High Order Taylor-Galerkin and Adaptive hp Methods for Second-Order Hyperbolic Systems: Application to

Elastodynamics," *Computer Methods in Applied Mechanics and Engineering*, v. 103, nos. 102, pp. 187-230.
Ainsworth, M. and Oden, J.T., "A Procedure for A Posteriori Error Estimation for hp-Finite Element Methods," *Computer Methods in Applied Mechanics and Engineering*, Vol. 101, 1992, pp. 73-96.
Ainsworth, M., Oden, J.T., and Wu, W., "A Posteriori Error Estimation for hp-Approximations in Elastostatics," *J. Appl. Num. Math.*, 14, 1994, pp. 23-54.
Oden, J.T., "Optimal hp-Finite Element Methods," TICOM Report 92-09
Oden, J.T., "Optimal hp-Finite Element Methods," *Computer Methods in Applied Mechanics and Engineering*, vol. 112, 1994, pp. 309-351.
Safjan, A. and Oden, J.T., "High-Order Taylor-Galerkin and Adaptive hp-Methods for Hyperbolic Systems," *J. Computational Physics*, vo. 120, 1995, pp. 206-230.
Oden, J.T., Safjan, A., Geng, P. and Demkowicz, L., "High-Order, Multi-Level Adaptive Time-Domain Methods for Structural Acoustics Simulations," *Large-Scale Structures in Acoustics and Electromagnetics*, National Academy of Sciences, September 1994, TICAM Report 94-14.
Duarte, C. Armando and Oden, J.T., "H-p Clouds -- an h-p Meshless Methods," *Numerical Methods for Partial Differential Equations*, Vol. (1996), (in press).
Duarte, C. Armando and Oden, J.T., "A New Meshless Method to Solve Boundary-Value Problems," Proceedings of the XVI CILAMCE-Iberian Latim American Conference on Computational Methods for Engineering, Curitiba, Brazil, November, Machado, R.D. (ed)., 1995, pp. 90-95.
Duarte, C. Armando and Oden, J.T., "Hp Clouds -- A Meshless Method to Solve Boundary-Value Problems," TICAM Report 95-05, May 1995.
Duarte, C. Armando and Oden, J.T., "An h-p Adaptive Method Using Clouds," TICAM Report 96-07, February 1996.

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